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INCREASING VALUE OF WASTE PRODUCTS<sup>1/</sup>

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Probably no country has been so profligate with its natural resources as America. In the acquisition of fortunes running into millions of dollars pioneer industrialists destroyed and wasted billions. Witness the destruction by the lumber industry of the wood stands of Michigan, Wisconsin, and Minnesota. Even today with improved practices in the lumber and pulp-wood industries the waste is still enormous and creates a national problem. Industry is alive to this problem and research expenditures of considerable magnitude are directed to a rational use of waste forest products.

America awakened to the necessity of natural resource conservation less than 50 years ago. The outstanding progress made in this country in its industrial process development has been based more and more on the elimination of wasteful processes and practices and on the conservation of materials, energy, time, and labor. During the course of this progress, which has been notable, it has become clear that waste elimination and the utilization of waste products depends most often on the development of new information and is, therefore, a joint problem of management and research.

The fuel industries are much in the public eye today. The coal and petroleum industries 25 years ago were fairly comparable in wasteful practices. Today the petroleum industry in its high chemical and technological development has become a leader in waste utilization. Some of our most important industrial chemical developments are now based on what were once waste petroleum products. Aside from some improvements in materials handling, progress in coal mining and in coal utilization has been meagre.

Farm wastes or, preferably, agricultural residues constitute one of the major unsolved waste utilization problems, not only in America, but the world over. Two hundred million tons of straws, stalks, cobs, shells, hulls and the like are produced annually on American farms. Conceivably half of this cellulosic material might become available to industry, but industry now uses less than 2 million tons. This problem holds little attraction for industry, but is of supreme importance to agriculture and to our future national economy. Residues represent more than half of the dry matter of our annual crops. A sound agricultural and industrial economy requires their most efficient use, which in turn will produce the maximum return to agriculture.

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The federally-financed problem of agricultural residue utilization was assigned to the Northern Regional Laboratory in Peoria, Illinois. This problem is not new and thousands of scientific papers, patents, and descriptions of processes for the industrial utilization of one or another of these residues are found in the literature. On the other hand, successful industrial utilization of any permanent character, in the light of the effort expended, has been very small.

With such a background of failure, the development of a rational, long-range program for a successful solution of this problem of waste utilization in 1939 was more than ordinarily difficult. From a study of the successes and failures in this and other waste utilization fields, several rather simple guiding principles for research were developed. Such success as the few succeeding years have brought to this work is due to adherence to these principles. They may, therefore, be of assistance to workers in other fields of waste utilization.

These principles may be stated briefly:

1. Establish procurement of the waste material on a sound economic basis. This involves collection, packaging, transportation, storage, and preservation and sound contractual relationships with suppliers.
2. From a thorough study of the physical and chemical properties of the waste material determine wherein it may render services in industrial usage not so readily supplied by other raw materials. Establish uses based on its superior or unique properties.
3. In process development to utilize a waste, eliminate waste products to the greatest possible extent. Attempt to obtain the maximum utilization by producing major co-products instead of byproducts or wastes.
4. Recognize that markets must be explored, merchandising plans perfected, and proper financing arranged before investment in plant facilities is made. Sound business management and sound merchandizing of the product will prove as important to success as a sound conversion process, operated on an economical competitive basis.

A number of examples can be selected from the field of successful and unsuccessful utilization of agricultural residues that illustrate the application of these principles rather well.

When the strawboard industry (1) was established in the Midwestern states about 50 years ago, the problem of straw procurement was rather simple and soundly organized. Wheat growing was widespread and most farms had surplus straw stacks. This straw could be baled throughout the year with stationary balers and transported relatively short distances to the operating mills. The procurement problem fell into the hands of contract balermen to a considerable extent and often the strawboard mill maintained



no direct financial contact with the supplying farmers. The price paid by the contract balerman to the farmer was as low as possible with the unhappy result that, with changing agricultural practices and crop diversification in the late 1920's, the farmers' interest was not tied in with the paper mill, and he received so little for his surplus straw that no consideration was given by him to providing straw for this industry. Almost concurrently a change in farm practice from the thrasher-binder method of harvesting wheat to the combine harvester method arrived in the Midwestern States. Unfortunately, no pick-up balers for securing combined straw spread on the fields had been developed and the strawboard industry has since been in a difficult situation with regard to the procurement of satisfactory straw. Today these mills go as far west as Kansas, Nebraska, and the Dakotas to procure sufficient straw. Freight paid to the railroads exceeds the price paid to farmers and baling costs. This situation is being remedied. Farmers are being paid better prices. A better understanding between farmers and strawboard mills is being developed by the mill operators. Recently the major manufacturers of pick-up balers and representatives of the operating strawboard mills met at the Northern Laboratory to discuss this mutual problem of straw procurement.

Obviously, residues which result from primary processing are more attractive for industrial use since they collect in a few locations in much larger tonnage than would be ordinarily available on a single farm. It is for this reason that sugarcane bagasse has attracted so much attention as an industrial raw material, since sugar mills may collect from 10,000 to 25,000 tons of dry bagasse in a grinding season. Nevertheless, when the insulating building industry was started in Louisiana, almost 30 years ago, handling, baling, transporting, storing, and preserving bagasse as a uniform raw material for year-round manufacture were problems of major importance which required several years for satisfactory solution (2).

The problem of preserving fibrous raw materials used in such bulk that they must be stored in the open offers serious technical difficulties. With the increasing price of wheat straw, the strawboard mills have become sufficiently interested that a month or so ago representatives of strawboard mills and manufacturers of chemical fungicides met at the Northern Laboratory to set up a comprehensive program looking to improved preservation of stored straw.

At present no satisfactory economical method of collecting cornstalks exists. An insulating board manufacturer in Iowa, who for some years has used cornstalks as a raw material, has finally discontinued their use on this account. If cornstalks are collected in the dead of winter, they are in a dry condition and the storage problem is not so serious but the costs of collection are high. It would be more rational to collect cornstalks at about the time that corn is harvested. At this period of the year, however, the cornstalk often contains 40 to 50 percent moisture and the problem of storing baled stalks collected in this condition is not only unsolved but has never really been studied.

Cotton stalks have often been talked about as a source for paper or board. No method of collecting cotton stalks has been worked out. All of these problems can be solved and the collection of such material, all in all, is probably no more difficult than the collection of pulpwood, particularly hardwoods in some localities. As you know, a revolution is taking place in the methods of collecting and handling pulpwood and in the endeavor to better utilize the forests' wastes.

Certain processes based on the utilization of agricultural residues have withstood competition for many years because superior products could be manufactured from these raw materials. The use of esparto grass by the English papermakers was started in 1860 at about the same time that the groundwood process, the soda process and the sulfite process for producing paper pulps from wood were invented. In spite of the tremendous technological advances made in the wood pulp industries, the English prefer esparto grass for the manufacture of Bible, fine book, and other fine papers, and, as a matter of fact, little change has been made in the process for pulping esparto grass during all this time. Obviously, the fundamental character of the true esparto fiber itself is responsible for this preference.

The possibility of utilizing seed-flax straw for paper manufacture was carefully investigated by several able workers in a period of 20 years before World War II and it was concluded in each case that while papers having properties superior to those manufactured from wood pulps could be produced from the tow obtained from seed-flax straw, the economics were against the use of this raw material. Today most of the cigarette paper used in the world is manufactured from the tow from seed-flax straw grown in Minnesota, the Dakotas, Iowa, California, and Canada (3). It is not possible to manufacture satisfactory cigarette paper from wood pulp. The success of this rapidly growing industry is to be attributed to a careful evaluation of the flax tow fiber and its preparation into fine pulp, coupled with a thorough study of methods for collecting and securing the tow. In addition to the use of this fiber for the manufacture of cigarette paper, it is found to the extent of 25 percent in our currency paper because of its scuff resistance and it finds use also in the manufacture of the finest air mail and writing papers.

For many years wheat, rye, and rice straws have been used for the manufacture of fine papers in Holland, Germany, Italy, South America, and Java. A mill in the Argentine produces 90 tons of bleached straw pulp per day. Our viewpoint in developments in the use of agricultural residues for the manufacture of paper is to use the pulps for the manufacture of paper specialties. The endeavor is not to replace wood pulp but either to produce a product not so readily made from wood pulp or to add residue pulps to wood pulps to produce paper specialties which neither type of pulp alone can produce. The use of wheat straw for the manufacture of strawboard has withstood vigorous competition because wheat and rye straws appear to be the best suited raw materials to produce the



highest grade 9-point corrugating material. In our studies on the pulping of wheat straw for fine papers, we are attempting to obtain pulps containing high percentages of pentosans since this gives high pulp yields. In a new process, the details of which will be published shortly, we are now able to obtain a 50-percent yield of bleached (70 brightness) screened pulp. This pulp is easy to hydrate, requires little power, and the fiber characteristics are such that they will give sheets of the excellent formation required for magazine, book, and writing papers when these pulps are used as blends with certain wood pulps.

Sugarcane bagasse has proved to be an outstanding raw material for the manufacture of a wide range of insulating and hard board building and structural materials (2). The long, tough springy fibers of bagasse when properly handled and refined, can be felted into board products of low density and high strength, particularly impact strength. High impact strength produces ruggedness in these products and prevents damage in rough handling. Our studies on the fundamental properties of agricultural residue fibers in relation to their ability to produce building and hard boards have now shown that wheat straw is a raw material fully comparable with, or perhaps better in some ways, than bagasse. As a result of this fundamental work, the Laboratory has developed and is prepared to discuss processes for the manufacture from wheat straw of a wide range of building materials in board form.

The development of many of our older industries has centered around the production of but one product; the question of recovering values from wastes or byproducts has been a secondary issue. The profits from by-product utilization, together with the stream-pollution problem, have brought a different conception to those engaged in process development. Many chemical engineers, instead of looking at process development from the standpoint of a main product and one or more byproducts, are beginning to consider the development from the standpoint of producing as many main products as can be merchandised. Any remaining values in the way of fuel or otherwise are recovered from products which are not in a form or cannot be economically put into a form of merchandise. The paper and pulp industries are good examples of an old industry that has been faced with a serious problem of waste disposal. Some of the larger companies of this industry have already reached the conception that they are in the business of the utilization of wood products rather than in the business of pulp and paper. In the development of processes for the utilization of agricultural residues, it seems rational to approach the problem from the standpoint of obtaining the maximum money return from each constituent in the residues. There will be, of course, some waste material in any process but with an economy of rising labor costs and diminishing resources, the process which will survive must be tailored sharply from the angle of maximum return.

For more than 100 years attempts have been made to produce fermentable wood sugars economically. The Scholler process was of great value to the Axis powers during World War II. A process much simplified in design and in operation, based on the Forest Products Laboratories' modification of the Scholler process, is now being operated in Oregon to produce sugars from waste wood. It is recognized that if sufficient return could be obtained from lignin the process could be operated on a competitive basis with blackstrap molasses but the tonnage of lignin produced, coupled with the fact that no satisfactory use for lignin as a raw material is yet in sight, leaves the question still open. In practically all processes proposed for the production of wood sugar, both the pentose and hexose sugars have been obtained together in solution. The hexose sugar is fermented to alcohol but it has been difficult to obtain full value from the pentose sugar remaining. Agricultural residues have never been seriously considered as a source for wood sugar. Wood contains generally more cellulose than residues, and since glucose is the chief sugar sought, wood appeared to be the logical raw material. On the other hand, agricultural residues are rich in pentosans and have been found to be the best source for the manufacture of the chemical, furfural, which is derived from the pentoses by treatment with mineral acids, about 200,000 tons of corncobs, oat hulls, rice hulls, and cotton-hull bran being used annually for this purpose (4). In the present process for producing furfural, as the sole product, the residue which consists of lignin and greatly degraded cellulose is used as fuel or as a filler for fertilizer. If agricultural residues are to be used as a source for wood sugars, it is evident that the high pentosan content must be capitalized and a process yielding pentose and hexose sugars separately, leaving a lignin residue, would be one on a sound economic basis. It would be necessary to obtain these sugar solutions in high concentration and in very high yields. This indicated a continuous process. Starting on this premise a process was developed at the Northern Laboratory (5) in which 95 percent of the pentosans in corncobs can be brought into solution mostly as pentose sugars with some furfural and with less than 1 percent dextrose. The concentration of the pentose sugar solution can be brought to 15 percent. The residual cellulose can be converted in 90-percent yield to dextrose in a solution of 10-percent concentration. The Laboratory has demonstrated that the solution of pentose sugars can be fermented satisfactorily to butanol, acetone, and alcohol or converted in high yield to furfural. The glucose solution ferments to alcohol in industrial yields. It is also probable that corn sugar can be crystallized from this solution. Preliminary costs estimates were sufficiently interesting to warrant operation of a semi-works plant in Peoria under a special appropriation from the Synthetic Liquid Fuels Investigation of the Department of the Interior. This is an attempt to obtain full utilization of cellulose, hemi-cellulose and lignin from residues such as corncobs, sugarcane bagasse, stalks, straws, seeds, seed hulls, and the like.



Many of the industrial attempts to use residues have failed not only because some of the principles discussed here were not met but because the market situation and the problem of merchandising were not understood or properly explored by the promoters of the ventures. During World War II many small rural grinding plants to produce ground cobs for various purposes were started. In many cases investment in plant facilities was made before a determination of sales outlet was carefully considered. As might be expected, quite a number of these plants have had to close down. Various attempts have been made in this country to produce paper from bagasse, comstalks and rice straw. In most cases the processes were promoted by persons who had no real understanding of the problem. In several cases the plant was built on a scale too small to operate economically. The best use of the fibers produced in the pulping process was not really explored or understood. Failures of this character in the use of waste products are perhaps the most serious obstacles to progress in waste utilization. Often the venture has been over-publicized during the promotion period and when the project fails the public gains the impression that failure is due to the fact that the waste product used as a raw material will never have any real value or use.

From this discussion it is clear that successful waste utilization is not a haphazard result. By applying the principles outlined or similar guideposts the incidence of success is greatly favored. The opportunities for successful utilization of waste through the joint efforts of agriculture and industry are many.

#### References

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